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ARTÍCULO POR INVITACIÓN

SMALL-SCALE SHRIMP FISHING IN SEARCH OF SUSTAINABILITY IN THE MAGDALENA-ALMEJAS LAGOON SYSTEM, BAJA CALIFORNIA SUR, MÉXICO: A REVIEW

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ABSTRACT. The coastal lagoon system Bahía Magdalena / Almejas (BM/A) at the Pacific coast of Baja California Sur, México, is a large water body extremely important for ecological, economic and social reasons. Because of its natural environment BM/A was declared as one of the areas deserving marine conservation priority. The exact number of fishermen and their families living around the Bay is not known, and neither is the currently registered small boats in service, nor the fishing efforts, expenses and yields. Recently, several civil organizations started working in the BM/A with the mission to solve some of the identified environmental and social problems. However, because of the lack of reliable data, wide spread corruption, and undirected and uncoordinated research make it very difficult to suggest ways to improve the livelihood of the small-scale shrimp fishermen without endangering the environment. Some promising options are small-scale aquaculture projects, mainly for off-shore mollusks production, and to offer eco-tourist activities as well as eco-friendly sport fishing. Both bring local employment opportunities while maintaining a quality environment.

Keywords: Bahía Magdalena/Almejas, shrimp fishing, livelihood, environmental sustainability

En busca de sustentabilidad de la pesquería de camarón a baja escala en el sistema lagunar Magdalena-Almejas Baja California Sur, México: una revisión

RESUMEN. El sistema lagunar Bahía Magdalena / Almejas (BM/A) ubicado en la costa oeste de Baja California Sur, México, es un cuerpo de agua de extrema importancia bajo las perspectivas ecológica, económica y social. Dado su ambiente natural, BM/A es considerada un área prioritaria en términos de conservación marina. Se desconoce cuántas familias de pescadores viven entorno a la bahía, así como el número registrado de embarcaciones pequeñas en activo, el esfuerzo pesquero, sus gastos, o su rendimiento. Recientemente, varias organizaciones civiles comenzaron labores en BM/A bajo la consigna de resolver algunos de los problemas ambientales y sociales identificados. Sin embargo, debido a la falta de datos confiables y a la corrupción, aunados a investigación mal dirigida y sin coordinación, dificultan la posibilidad de sugerir maneras de mejorar la sustentabilidad de la pesca menor de camarón sin poner en riesgo el ambiente. Algunas alternativas prometedoras son los proyectos acuaculturales a pequeña escala, principalmente para producción de moluscos lejos de la costa, así como las actividades ecoturísticas y la pesca deportiva ecológicamente amigable, dado que ambas abren oportunidades de empleo locales conservando la calidad del ambiente.

Palabras clave: Bahía Magdalena/Almejas, conservación, pesca de camarón, sustentabilidad ambiental

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INTRODUCTION

The biological importance of the Magdalena-Almejas lagoon system

The Bahía Magdalena and Bahía Almejas (BM/A) lagoon system is located about 250 km northwest of La Paz, the capital of the State of Baja California Sur. It is the largest lagoon system on the Pacific west coast of the Baja California Peninsula, covering 1,500 km^2, with a shoreline of 1,200 km. It is about 200 km long extending parallel to the coastline, and about 20 km across at its widest point. It has deep-water channels (up to 40 m) and large expanses of shallow intertidal areas (Fig.1).

Bahía Magdalena-Almejas is located at the meeting of the two most important water currents of the Western Pacific: the cool California Current system from the north, an extension of the Alaska Current, and the warmer counter-current from southern Mexico. At this juncture of these two current systems, conditions are created offshore for strong nutrient upwelling, causing rich planktonic growth, which serves as food for pelagic crustaceans and fishes. The confluence of the two currents also creates unique water temperature profiles and nutrient fluctuations thought to be the primary contributor to the astonishing biodiversity of the region. The system has been identified as one of the richest lagoons in the world (Álvarez-Borrego & Schwartzlose, 1979; Álvarez-Sánchez *et al*., 1978; Morgan *et al.*, 2005; Bizarro, 2008). The Commission for Environmental Cooperation of North America and the Marine Conservation Biology Institute include Bahia Magdalena for marine priority conservation within their 28 areas ranging from Baja California to the Bering Sea (Morgan *et al*., 2005). This niche and near-shore waters are important nurseries for numerous commercially valuable species of crusta-

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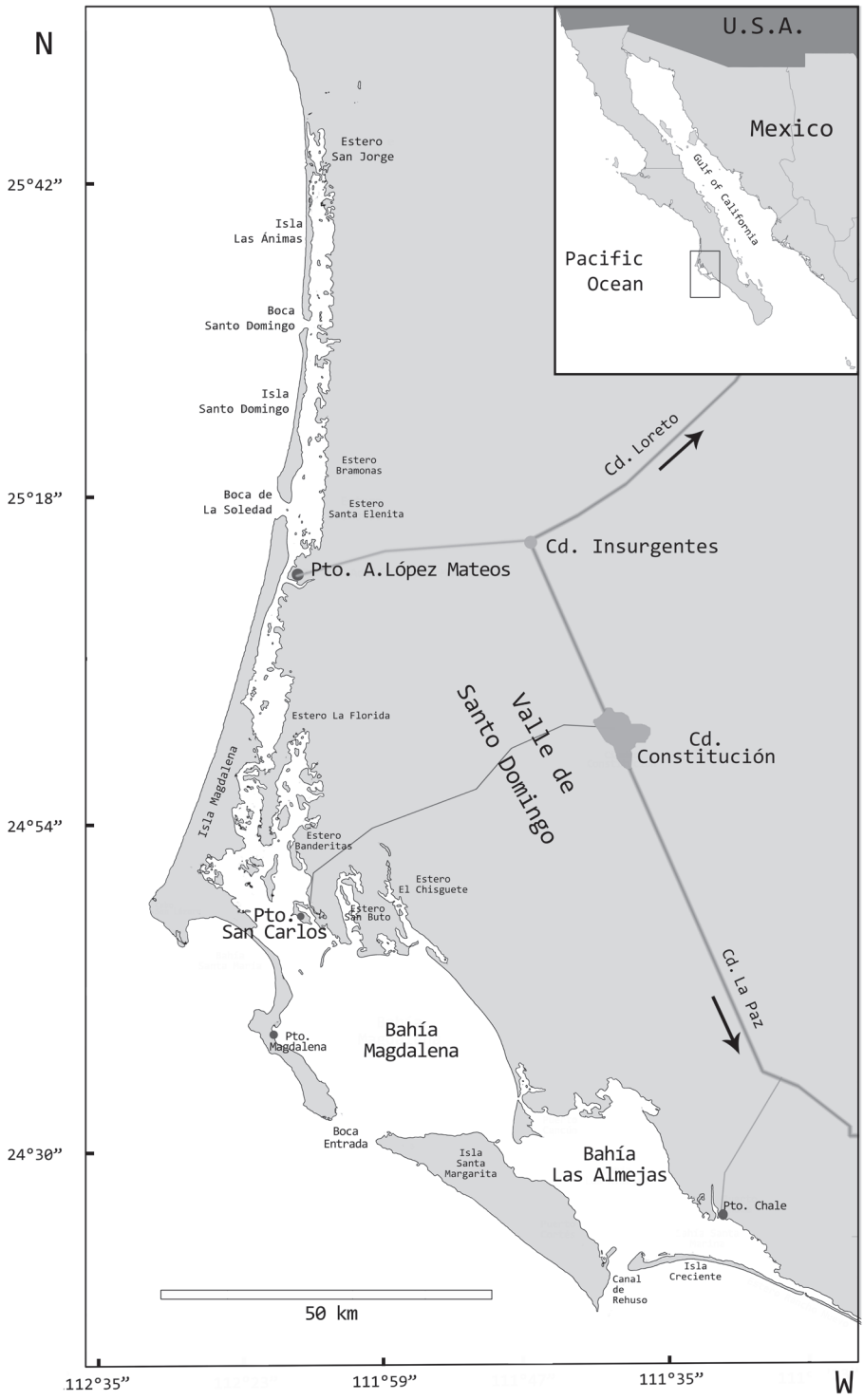

Figure 1. Bahía Magdalena/Almejas lagoon system.

ceans, fish and shellfish, including abalone (*Haliotis* spp.), lobster (*Panulirus* spp.), Pacific calico scallop (*Argopecten circularis*), Pismo clams (*Tivela stultorum*), shark (*Squalus* spp.), yellowleg and blue shrimp (*Farfantepenaeus californiensis* and *Litopenaeus stylirostris*), Pacific sardine (*Sardinops sagax*), Chub mackerel (*Scomber japonicus*), California anchovy (*Engraulis mordax*), and other marine species. All these species are commercially important and are the economic backbone; indeed the most important economic activity of the population centers, villages, and fishing camps that are scattered along the coast of the lagoon system. It is estimated that at present about 20 000 families are more-or-less dependent on harvesting and processing the fishery resources of the system (School for Field Studies, 2004).

Historical use of the Magdalena-Almejas lagoon system

Natural resources of the lagoon system have been intensively exploited; between 1845 and 1874 whalers from North-America caught about 2000 grey whales in the lagoons, more than any other site along the coast of the peninsula (Saad-Navarro & Palacios-Castro, 2004). As E. Young (1999) describes, "Fishing communities, however, in the Bay of Magdalena are relatively recent. Indigenous populations that once exploited the Valle de Santo Domingo near-shore waters were virtually wiped out by diseases, as a result of early European contact and colonization. Pioneer settlers initially migrated seasonally from inland ranches and population centers to the Pacific coast to harvest lobster, shark, and sea turtles for sale to merchant ships from San Diego. Settlers also fished to supplement their often meager ranch supplies. Seasonal fishery camps gradually grew into permanent settlements, as more and more people moved to Bahía Magdalena/Almejas in the hope of securing a better life from the sea."

At this time, the municipality of Comondú, relatively close to the lagoons, was the poorest in the state. The broad, mostly flat area to the east, the Valle de Santo Domingo Plains, became a center of agricultural development, starting in the 1960s. Farmers received subsidies from the federal government to buy seed, fertilizer, and insecticide, and special advantages to obtain bank loans (Barrett, 1974). This agricultural development mainly attracted male workers from as far as Nayarit and Oaxaca to work in the fields as daily paid laborers.

Puerto San Carlos, a port in Bahía Magdalena, was built in 1969 to export the harvest, mainly wheat and corn, to the interior of Mexico and even to Japan. Irrigation required extensive extraction of ground water, leading to saltwater intrusion and diminished production. By 1981, the federal government stopped its subsidies, particularly for credit. This led to considerable unemployment in the region, where nearly 70% of the population was economically dependent on agriculture and living far from their home region (Saad-Navarro & Palacios-Castro, 2004). For many, fishing for shrimp and collecting mollusks in the lagoons was the only possibility for survival.

In 1970, a governmental fish processing plant was established in the port of López Mateos, located in the Channels Zone to the north of Bahía Magdalena. The plant processed sardines caught along the Pacific coast with its own fishing boats, shellfish from local fishing cooperatives, and tuna from private boats. To attract workers, the plant offered generous benefits, including free housing, basic services, and medical care. The cannery at this time was the primary source of employment and the mainstay of the local economy. There were only a few households whose members worked as free fishermen in the bay, along with one local cooperative. In the early 1980s, this situation began to change. A growing number of immigrants arrived, mainly from Sinaloa. Since 1990, the North America Free Trade Agreement (NAFTA) brought reforms, resulting in a huge opening of the Mexican economy and increased political and economic costs coupled with a reversal of trade policy and restrained trade with other countries. The market-driven approach to economic and social policy stressed private enterprise, liberalized trade, and relatively open markets. The Mexican government reduced subsidies for fishing and opened the cannery for privatization. These interventions had profound social impacts on the population of Puerto López Mateos. In 1995, many seasonal cannery workers were laid off and only 44 permanent workers remained, causing a rapid and massive rise in unemployment (Young, 2001). To find alternative income, small-scale shrimp fishing in the previously commercially unexploited channels and the lagoons were particularly attractive to fishermen from Sinaloa, who had previous experience in shrimp fishing on the mainland (Young, 2001).

Also in 1990, the federal government constructed an electric power plant north of Puerto San Carlos to service the inhabitants of the bay and surrounding areas, as well as to provide energy to pump ground water from deep wells to irrigate large-scale farms (Dedina & Young, 1995). It was hoped that the opening of industrial sardine processing and canning plants would reduce pressure on the local employment market, but on the very few industrial sardine boats based at Puerto San Carlos and Puerto López Mateos, only a few men were employed, and mainly women were employed at the processing plants (García-Martínez, 2005; García-Martínez & Chávez-Ortíz, 2007). Unemployed fishermen focused their attention on small-scale operations, mainly marine species, such as shrimp and mollusks that had market demand. Currently in Puerto

San Carlos, fishing is the most important economic activity.

Puerto San Carlos has more than 3,500 permanent residents and, mainly during the shrimp season, 2,000 transient fishermen and this leads to an extreme change in population size (García-Martínez, 2005; García-Martínez & Chávez-Ortíz, 2007; Chávez-Rosales *et al*., 2008). At Puerto San Carlos, 47% of the active population are working in fisheries, 28% in fish processing, 20% in trade, and 5% in tourism (Chávez-Rosales *et al.*, 2008). Income from fishing is slightly higher than income from fish processing, but because of high cost of living in the area, income is not sufficient to cover a family's basic needs. This leads to strong pressure to exploit natural resources more than is officially permitted (García-Martínez & Chávez-Ortíz, 2007).

Official data about the exact number of small fishing camps scattered around the large lagoons and the quantity of captured natural resources reported at the landing sites are missing, incomplete, or not trustworthy. There is no reliable information about the number of families, fishermen, boats, and harvest to support a sustainable livelihood without endangering the natural resources. To verify overexploitation of the shrimp and fish stocks in the BM/A lagoons and allow estimates for sustainable development, without endangering natural resources, it is necessary to consider more than biological data. A multi-disciplinary team, sociologists included, is necessary to obtain reliable data with the cooperation of fishermen, government agencies, civil organizations, and researchers. The socio-economic situation of small-scale fishery communities needs to be understood and programs to obtain additional income for fishermen are essential.

Evolution of shrimp trawling in the lagoon complex

Previously unexploited for commercial use in the bay, shrimp was particularly attractive to fishers from Sinaloa. To find an alternative subsistence income from agriculture in the Magdalena Plain and from fish processing at Puerto López Mateos, unemployed workers started to engage in small-scale shrimp fishing in BM/A, using skiffs (pangas) smaller than 7 m and with outboard motor of less than 55 hp. In 1997, trawling gear for shrimp fishing was restricted to inshore waters (0 – 9 m depth) to reduce the effects of these nets on benthic habitats (Chavez-Rosales *et al.*, 2008; CONAPESCA, 2013).

Shrimp-trawling is, for the small-scale fishery, the most important source of income in this region. Nevertheless, this activity has serious impacts on the physical and biological environment of the marine ecosystem and the diversity and quantity of by-catch and discards (Biju-Kumar & Deepthi, 2006). By-catch from shrimp-trawling was recorded in Puerto San Carlos, amounting to145 species in 67 families and 97 genera; and of these about 80% were dead juvenile fish, mainly seabass and groupers (De la Rosa Meza, 2005). So, the shrimp-trawling fishery should be referred to as multi-species trawl fishing (Eayrs, 2012).

Pacific shrimp fisheries discard up to 80% of the harvest (Bojórquez, 1998). For each kilogram of shrimp harvested by trawling in the BM/A lagoon system, up to 15 kg of fish by-catch are collected, most of which are discarded (Bain Smith, 2004). To use the by-catch, fishermen could earn additional income by smoking the larger fish and producing meal and silage from the smaller ones as an ingredient in animal feeds (Slavin, 1981; Ramírez, 2013). This could result in a more holistic approach to the problem, but this resource is currently wasted. In Asian countries, by-catch from shrimp trawling is not discarded; the full catch is used for human consumption or as feed for livestock (Clucas, 1997; Kelleher, 2005). Researchers and government officials need to work together with small-scale shrimp fishermen to reduce the volume of by-catch and use what is caught (Hall *et al.*, 2007).

Lack of appropriate fishing gear for selected species and habitats add to the threat to aquatic life. By shrimp trawling every square meter of the floor of the BM/A lagoon is ploughed at least twice annually (School of Field Studies, 2004). The impact of by-catch and bottom-disturbing trawling has yet to be determined in BM/A but similar impacts have been documented globally (Watling & Norse, 1998; Kaiser, 2000; Simpson & Watling 2006). The dead by-catch is made up partly of juvenile fish of commercially important species, which will have a negative impact on recruitment and on the ecology and harvest potential (De la Rosa Meza, 2005). The by-catch of sea turtles in trawl and gill nets in the BM/A lagoons and mangrove channels is an important factor in the lack of their population recovery.

Today shrimp trawling in the BM/A lagoon is legally permitted only between September and the beginning of March (CONAPESCA, 2013). From 1998 to 2009, there was an average harvest of about 500 tons of shrimp per season, with a value of about 2.7 million US$ (Ojeda Ruíz de la Peña & Ramírez-Rodríguez, 2012). CONAPESCA (2013) reported in 2010 that at Puerto San Carlos the harvest was nearly 700 t of de-headed shrimp, for a value of 4.0 US$/kg. The Sustainable Fisheries Partnership (www.sustainablefish.org/fisheries-improvement/shrimp/magdalenaBay) reported that the Bahía Magdalena shrimp fishery generates annual landings of 1,395 t worth US$7.8 million, 65% was exported to the U.S. in different value-added forms. The remaining 35% was marketed in México as fresh and frozen products. The amount of landed shrimp at the many other landing sites around the BM/A lagoon system is unknown. The 720 registered panga boats in the lagoon harvest about 500 t of shrimp per season

(García-Martínez & Chávez-Ortiz, 2007). In 2007, a simulation model was developed to estimate a maximum sustainable yield of nearly 600 t of shrimp and this required no more than 215 pangas with trawling gear to avoid over-exploitation (García-Martínez & Chávez-Ortiz, 2007). Considering the large number of registered and an unknown number of unregistered pangas, shrimp-trawling in the lagoon system is not sustainable. Ojeda Ruíz de la Peña (2012) reported that there are 1,000 fishing pangas distributed among 95 cooperatives, with nearly 400 permits to fish for shrimp. Gambill and Schneller (2011) report that over 340 cooperatives and organizations of fishermen work only in Puerto San Carlos. Membership permits legal fishing during the open season and its members and family to be covered by the government health insurance system. The cooperatives hope, particularly during election periods, to obtain government subsidies to purchase new boat engines and fishing equipment for its members.

Finally, an additional handicap for small-scale shrimp fishermen is that most of them are excluded from direct marketing of the fresh product, since this activity is controlled by middlemen having capital and under-the-table money for permits to legally transport the catch from the beach to the market (García-Martínez, 2005). For this reason, most of the shrimp fishers sell their harvest straight at the landing place and on the street without asking for an official sales receipt. From official sales obtained from shrimp processors and public markets the cooperatives charge a quota. The sales receipts are next transferred to the Secretariat for Agriculture and Fisheries (SAGARPA) and at the end to the Finance Office to collect from the fishermen the income tax. Unfortunately, researchers are using these "trip tickets" to determine the quantity of the shrimp harvested in the BM/A lagoon system, without considering the fishing efforts, hours trawled per day, expenses (mainly for fuel), number of hauls per day and the exact location of the fishing operation.

Collecting mollusks and fishing near shore is helping fishermen to increase their income. From the middle of December until March the collection of the Pacific calico scallop (*Argopecten circularis*) and the Catarina scallop (*Argopecten ventricosus*) is permitted, and from September until January, a limited number of cooperatives have exclusive access to collect abalone (*Haliotis corrugata* and *H. fulgens*) (Ojeda Ruíz de la Peña & Ramírez Rodríguez, 2012). In Bahía Magdalena, about 12 t of abalone are caught yearly for a value of US$ 135,000. The high market value of abalone creates a strong temptation for poaching by fishermen that are not in cooperatives, combined with the fact that arrest by authorities of poachers is unlikely (Bórquez-Reyes *et al.*, 2009). Finally, for small-scale fishermen, the collection of scallops, using air-supported diving gear represents an important income. From 1998 through 2009, the average harvest was about 7,000 t per season for a value of about US$ 530 per ton (Ojeda Ruíz de la Peña & Ramírez-Rodríguez, 2012).

Role of government institutions to support small-scale shrimp fishermen and conserve the BM/A lagoon system's natural resources

To reduce environmental impacts by small-scale fishing, the federal government limits the number of fishing permits, size of a crew to three men per boat, and nets to two traditional cast nets or one improved trawl net. However, the exact number of fishing cooperatives and their members and the number of independent or illegal fishermen is unknown (García-Martínez & Chávez-Ortíz, 2007). In the last decade, trawl nets have been redesigned to reduce the by-catch and discards from shrimp fishing, mainly young fish and turtles. The National Fisheries Institute accepted the challenge to design and test different trawl nets, but reliable comparative data about by-catch and usefulness in shallow waters are not available (Aguilar *et al.*, 2001; Aguilar *et al*., 2013).

One of the local socio-economic concerns about small-scale shrimp fishing is insufficient scientific assessment and monitoring of the resources available for the government such that they are able to develop effective fisheries management plans. Given the inefficiencies and wide spread corruption of government agencies and the lack of adequate enforcement, the natural resources of the BM/A lagoon system will not indefinitely hold up to increasing and uncontrolled exploitation.

Communication and honest collaboration between government agencies, the trawl fishermen, and the researchers are missing; hence the best approach for socio-economic development of the fishermen and proper management of natural resources remains unresolved. In addition to the Regional Centre for Fisheries Research (Centro Regional de Investigación Pesquera (CRIP) two other research institutions in La Paz are supported with federal funds: The Centre for Biological Research of the Northwest (Centro de Investigaciones Biologicas del Noroeste, CIBNOR) and the Interdisciplinary Center of Marine Sciences (Centro Interdisciplinario de Ciencias Marinas, CICIMAR). The Autonomous University of Baja California Sur (UABCS) is supported by the state government of Baja California Sur. All of these academic institutions were founded in 1975–1976 without coordination or planning, without prior evaluation of the teaching and research needs to secure student employment after graduation, and assistance from private industry to develop support for sustainable livelihood of the small-scale fishermen, or conservation of natural resources. The needs of the small-scale fishing communities have been almost neglected, and most of the young researchers are focused in developing

programs that are not critical. Hence, there is only limited collaboration and exchange of information between government officials, researchers, and fishermen.

In recent years, over 200 research papers describing the physical and biological characteristics of the BM/A lagoon system and the fisheries have been published (Hinojosa-Medina *et al.*, 2007; Bizzarro, 2008), but detailed studies about socio-economic conditions of small-scale shrimp fishermen are totally lacking.

Few studies have addressed the problems of wide spread corruption and smuggling, even by some government officials with responsibilities in the BM/A lagoon system (Young, 2001; Saad-Navarro & Palacio-Castro, 2004). Additionally, frequent changes in the official regulations for shrimp trawling make it difficult for small-scale fishers to comply. The responsible agencies for inspection and enforcement lack the capacity and logistic support to effectively implement their responsibilities. Unfortunately, there is very little respect and support for the government officials by the local communities even though agency officials patrol a very large area: the coastal zone, open water, and mangrove channels. Low salaries, insufficient logistical support, antagonism with by the fishing community, and armed retaliation by poachers, among other problems, means that inspectors cannot be efficient, if they are honest. Small-scale fishermen catching with cast nets during the closed season bait shrimp in the mangrove area, for sport fishing, are subject to apprehension by inspectors. If the inspectors side with the fishermen, they receive a small amount of shrimp for ignoring the regulations. The circumstances predispose inspectors to be corrupt.

Non-government institutions working in the coastal lagoon system

One hope for development of a sustainable livelihood for small-scale fishermen and their families and conservation of natural resources in the BM/A lagoon system is collaborative participation of locals and non-government organizations (NGOs). It seems possible to promote understanding and respect for official regulations and environmental laws to conserve natural resources and strengthen collaboration with scientists to carry out resource-related research.

In the region, there are now several organizations documenting environmental threats, helping to improve community life, including the social-economic conditions of the shrimp fishermen. Pronatura Noroeste (www.pronatura-noroeste.org) was founded 1992 to promote development of local society in harmony with nature, linking alleviation of poverty with preservation of the environment (Saad-Navarro & Palacios-Castro, 2004). In 2009, the Ocean Foundation, with many years of experience in research and conservation, international environment policy, and community-based conservation, merged with Pro Peninsula (www.propeninsula.org), a NGO established in 2001. The merger was to strengthen individual and community efforts and to promote community conservation through two programs, Grupo Tortuguero and Proyecto Caguama, as well as strengthening the capacities of local, grassroots organizations to carry out research, conservation, and education. The NGO "Vigilantes de Bahía Magdalena" (www.waterkeepersbaja.org), was founded in 2005 to educate communities in co-responsibility, starting from festivals, like "El Festival Tortuguero", which attracts about 13,000 people each year to Puerto San Carlos. The organization monitors water quality and natural resources in the BM/A lagoons and presents data for pressuring the federal government to investigate law violations, stop sources of contamination, and guarantee conservation of species and their habitat.

The work of the School for Field Studies, with its campus in Puerto San Carlos, was of great importance as it was the only academic-based institution in the area. Founded in 1997, its aim was to strengthen, with students from the United States, research in ecology, biology, economics, and social science. The School tried to support the local communities by offering English classes, so that fishermen could find careers as tourist guides for nature observation and turtle conservation; it supported research and outreach activities, such as festivals and sustainable development education. One important activity was restoration of mangroves, planning of urban development, pollution remediation, garbage collection, and studies of the waste discharge into the BM/A lagoon by the sardine cannery (Ollervides & Farrell, 2007; School for Field Studies, 2007). In 2011, the School closed when student enrollment sharply declined, probably from perceptions of drug violence in México and warnings by the US State Department to students and tourists in México.

The International Community Foundation (www.icfdn.org) is supporting community-based opportunities and needs (International Community Foundation, 2006). In 2012, the Moreno and Associates (Moreno-Patiño, 2012) assessed for the International Community Foundation the possibility of rescuing the work and plans of the School for Field Studies by creating a new field station, combined with a community center in Puerto San Carlos. Officials from several government and non-government organizations, research centers and government offices were interviewed to determine their interests and possible financial contributions to establish a new research facility. Unfortunately, there were no positive results. Pronatura Noroeste, with The Resources Legacy Fund and Spitfire Strategies, developed a strategic plan for the BM/A lagoon system in a summary report. This involved interested organi-

zations and communities in topics such as fisheries regulation, protection of critical areas, promotion of responsible development, and building local interest to generate a movement headed by local communities in favor of conservation (Spitfire Strategies, 2009). In January 2009, the group had its first meeting and at the end of May 2009, a two-day workshop was held in La Paz. However, these initial efforts to develop the plan were not successful. The different organizations preferred to implement parts or small components of the plan. It was impossible to establish extensive coordination among the groups.

CURRENT SITUATION

Fishing pressure on the natural resources is high. The rapid influx of migrants to engage in the fishery sector coupled with diminishing harvests are the main reason for increased fishing pressure and thus impacts on the ecosystem's natural resources. The Sustainable Fisheries Partnership, a NGO dedicated to work directly with the industry, was contacted in 2008 by the shrimp export company, Tai Foong, USA, to start a fishery improvement project in the BM/A lagoon system. In the status report of the Sustainable Fisheries Partnership (2014) and the Fisheries Improvement Project about the conditions of shrimp fishing, they indicate the shrimp stocks are overexploited, but with some recovery (Sustainable Fisheries Partnership, www.sustainable.org). Recently, the number of migratory shrimp fishermen has decreased, due to lower shrimp harvests and reduced income. Official regulations are quite extensive, but at the operational level, such as the number of permits, maximum allowable catch, timing and duration of fishing seasons for the different resources, gear restrictions, and others) are based on old or insufficient stock assessment data. For some of the most commercially important resources, such as shrimp and scallops, biomass estimates are all that are used to determine the fishable portion of the stock in any given fishing season.

There are insufficient reliable data available on recruitment, growth, and mortality of these species to make more realistic stock management decisions. For almost all other commercially important species (approximately 70), no specific information is available, and catch limits, when they exist, are guesswork. Under such circumstances, stock assessment is not effective enough for confident management of an ecologically complex ecosystem and economically important resources. The fishermen have little confidence in the stock assessment data; therefore, they feel justified for ignoring regulations obtained from that data (School for Field Studies, 2007).

Lack of inspection and enforcement

It has been known for long time that management priorities for the BM/A lagoon system are fundamental for long-term economic benefits for fishermen, but also for conservation of natural resources (Hastings & Fischer, 2001). Diminishing shrimp harvests and fewer migrant fishermen are signs of continuing serious environmental problems. In a recent survey about the fisheries management in the BM/A lagoon, 100 fishermen were interviewed (Gambill & Schneller, 2011) and based on average rankings (on a scale of 0 to 10; 10 being the most severe) for them, the most important threats for fishing were corruption within the government (8.35), low market prices (8.34), lack of alternative economic opportunities (7.2), the lack of people abiding existing fisheries laws (7.06), and too many fishermen (7).

While it is not the place of NGOs to engage in enforcement, it is possible, through their community work, to promote respect for the regulations. The NGO, Natural History Society "Niparaja" in La Paz published a guide on how to apply for permits for commercial fishing (Niparaja, 2012), how to establish and run fishery cooperatives (Segura-Aguilar *et al.*, 2009), and what formalities have to be fulfilled to incorporate sport fishing, as an option for fishing cooperatives (Santana *et al.*, 2010).

To decrease fishing pressure on natural resources, regulations and enforcement are not sufficient. Ways have to be explored to offer fishermen alternative options for an income. This is becoming urgent because SAGARPA is working on a decree to forbid the use of trawl nets for shrimp fishing. Additionally, urgent solutions need to be found for the increasing problems of the fish-processing industry at Puerto San Carlos. Because of the decline in sardine fishery, the processing plants may be closed. A program should be developed to offer the about 1,000 in the future unemployed workers options for earning an income.

Preserving rich natural resources and offering other income opportunities to the fishing communities

Small scale shrimp fishermen need to work with civil organizations, governmental institutions, and the academic community to prevent further harm to the BM/A lagoon system. While observing regulations for the preservation of natural resources is imperative generating alternative sources of income for a sustainable livelihood, including opportunities for female workers laid-off from the fish processing plants in Puerto San Carlos. The current uncertainty of having a fair income is linked to the high rate of alcoholism, involvement in drug trafficking, and violence. Weak and non-traditional community structures create serious challenges to local support and participation to achieve success.

As mentioned earlier, by-catch from shrimp trawling is discarded. If a reliable market for smoked fish was developed, and practical training in building in building smokers, drying fish, producing fish meal for aquaculture enterprises or fish silage

to feed pigs and cattle was provided, this by-catch could produce additional income for fishermen families.

All possible opportunities to generate income must be evaluated, including access to markets and finding investors for sustainable development. Fishing-related opportunities, such as aquaculture, sport fishing, and eco-tourism are prime options as long as they are done in an environmentally-friendly manner.

Aquaculture

The most promising option in the short-run is aquaculture. During the past decade, aquaculture research projects were tested. If aquaculture activities are created in this region, special attention must be paid in protecting the mangrove ecosystem (Lagunas-Vazquez *et al.*, 2011). To find optimal places for development and reducing environmental impact, seven sites were found using satellite imagery and digitalized in a geographic information system. These areas would provide less impact and a higher probability of success for clam cultivation (Malagrino *et al.*, 2007). For shrimp farming in the supra-littoral zone, six areas were selected (Malagrino *et al.,* 2008). At sea shore intertidal channels, bottom cultivation of Catarina scallops (*Argopecten ventricosus)* was tried (Maeda-Martínez *et al*., 2000); also, the Penshell, *Atrina maura* (Mendo *et al*., 2011). In off-bottom cultivation the giant Lions-paw scallop *Nodipecten subnodosus* was tried (Koch *et al*., 2005; Osuna-García *et al*., 2008). The BM/A lagoon system has great potential for crabs (*Callinectes arcuatus*, *C. bellicosus*, and *C. toxotes*) where semi-cultivation operations in ponds in the shallow lagoons could raise the shore crabs or produce soft-shell crabs (Orozca-Ampudia & G. Goussen-P., 1994; González-Ramírez *et al.*, 1996; Chan Vadillo, 2014). Unfortunately, in these reports, the cost of operation was not included nor was the durability of the cultivation structures, the cost and availability of fry and juveniles, labor requirements, feed costs, and different processing and marketing options. These data are essential for a cost-benefit analysis.

Before preparing commercial aquaculture proposals and searching for investors, a multidisciplinary team has to be established, involving members of government and civil organizations to determine the legal requirements, environmental and social impacts, personnel with academic and practical experience in aquaculture, and economists to determine market options and develop a cost-benefit analysis for the different possibilities in aquaculture.

One of the few examples for a partly successful applied research and practical implementation of aquaculture in the BM/A lagoon is the work by Aviles *et al*. (1993, 2004), who designed net cages for the grow-out of Yellowtail Jack (*Seriola lalandi*). In 1991, the work started in collaboration with the company "Kalada de México" and the "Cooperativa Bahía Magdalena". Yellowtail fingerlings were collected in the wild but unfortunately, production was stopped in 1995 because of theft and the high cost of labor, imported feed, and no market in México, which would have meant exporting the harvested fish to the United States.

The work by Aviles *et al*. (1993, 2004) was recently reconsidered by BajaSeas, a company associated with the Hubbs-SeaWorld Research Institute, Carlsberg, California, to solve the problem of reproduction in captivity of Yellowtail. Hatchery fingerlings were shipped to the BM/A lagoon for the grow-out phase. At the same time a hatchery was built for Ocean Baja Labs, a BajaSeas company, on the Pacific coast in the northern part of the Baja California peninsula for reproduction and growing fingerlings. In the future, fingerlings will be grown-out by Ocean Baja Labs at their actual grow-out site in the BM/A lagoon. It contains 16 circular sea cages, about 20 m diameter and anchored 25 m over the seabed. Each cage is stocked with 120,000 fingerlings to produce annually about 2,000 t of marketable fish. To prevent overfeeding, an automatic feeding system is used to distribute the imported salmon feed. Only twelve workers from San Carlos are needed to maintain, take care, and guard the facility. For the marketing of Yellowtail, BajaSeas partnered with the California-based seafood distributor, Catalina Offshore Products, to bring the fish to selected restaurants in the United States.

For small-scale fishermen, raising mollusks offers much cheaper alternatives. To date, five cooperatives are working in the BM/A lagoon system. The cooperatives work with oysters raised in trays and other bivalve species (*Nodipecten subnodosus*, *Anadara* spp., *Megapitaria squalida*, *Atrina maura*, *Argopecten ventricosus*, *Panopea generosa*). Oyster spat is purchased from two facilities in La Paz, but the spat for the other bivalves has to be collected from wild specimens. At the moment, three cooperatives collect spat, and seven cooperatives are waiting for financial help to start. The oysters are mainly sold to selected restaurants in Cabo San Lucas resort area, about 500 km south of Puerto San Carlos. Since the quantity of cultivated oysters is small, processing is not yet developed in the BM/A lagoon system. Successful commercial oyster farms and processing facilities for export to the United States takes place in Laguna San Ignacio, north of the BM/A lagoon system. This activity plays today an important role for family income (Bautista González, 2014).

Nature Observation and Sports-Fishing

In the past few decades, watching grey whales (*Eschrichtius robustus*) became popular in the BM/A lagoon system. The rapid growth of tourists prompted the Mexican authorities to take emergency measurements to protect the breeding areas

of whales and dolphins (Flores-Skydancer, 1999). Official permits have to be obtained to use special boats for eco-tourism; these boats cannot be used for fishing. For this reason, small-scale fishermen are excluded from this activity; however, their small boats can take one or two tourists for nature observation and recreational fishing.

SUMMARY

Under the current political system and the uncertain future of the local shrimp fishermen to obtain a family income, the unique environmental beauty of the BM/A lagoon system, with its wide channels, remains uncertain. Unfortunately, researchers have failed to generate reliable data about the status of the shrimp stock. For the fishermen, alcoholism, violence and drug trafficking are not a solution. The recent development of small-aquaculture activities, sport fishing, and nature excursions are by far not enough for the hundreds of fishermen struggling to support their family. For these reasons, new ways must be found. In the past, unemployed workers from neighboring areas and the sardine processing plant in Puerto López Mateos found alternative fishing opportunities. Today, there are no alternatives to avoid unemployment. An enormous effort is required to improve the actual socio-economic situation of the local fishermen and their families and show them a way to have a better future. Training in the best uses of by-catch from shrimp trawling, and how to cultivate, process, and market mollusks could help. To communicate with tourists, illiteracy needs to be eliminated and English classes offered. For the youth, a better basic education and training in trades are needed to find employment.

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